STEP 3

E^{3}A: Small Wind Energy Applications for the Home, Farm, or Ranch

Steps in the Small Wind Series

E3A-SW.3
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Assess the Wind at Your Site

The wind resource is one of the key factors in a successful small wind project. You will need to assess the wind resource at your site. This guide will help you to understand the effects of wind speed, wind shear, wind distribution, prevailing winds, turbulence, and elevation.

You should take time to understand wind assessment and to gather some free information about your wind resource. This will help you to ask good questions when you are working with your installer. Your system installer should conduct a more in-depth analysis of the wind resource. Installers usually have more accurate data and assessment tools. You can also purchase better data. There are fee-for-service mapping tools available.

Note: Before buying wind data, make sure you know what data source is being used by the company. Some companies use free data for their maps. You could get the same information on your own!

Wind Speed

Wind Maps

You will need to find information on the wind speed at your site. The best way to get site-specific wind information is to install an anemometer and to collect data for at least one year. (The anemometer should be at the same hub-height as the planned wind turbine.) Installing a tower and anemometer can be expensive. Most homeowners cannot afford to collect anemometer data. For small turbines, the value of the data collected by an on-site anemometer is often not worth the cost. Therefore, free data is often used to estimate the wind speed. These estimates rarely reflect the actual wind resource of your site.

Free wind mapping data are available from:

- Department of Energy: Wind Powering America State Wind Maps: www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
- Renewable Energy Atlas of the West: www.energyatlas.org/
- National Renewable Energy Lab – In My Back Yard: www.nrel.gov/eis/imby/about.html

Wind maps are often created using a mix of publicly available data and wind modeling. It can be hard for a user to know the sources and quality of the data used to develop the wind map. These sources provide an indication of the wind speed, but understand that they are likely to have high degree of variability.

Sources of Local Data

Local data may be publicly available. These sources may provide an indication of the local wind speed. The data may not be accurate for your purpose. The data might be collected from anemometers on rooftops of rural airports, in sheltered areas or near trees that influence the wind. Agronomic weather stations collect data at five to six feet above the ground–well below a typical wind generator hub height. Some anemometers are located in

Understanding how wind turbines generate power from the wind may help you to realize the importance of the wind energy resource:

$$P = \frac{1}{2}\rho v^3 \Pi r^2$$

ENERGY=(1/2) X (AIR DENSITY) X (VELOCITY)^3 X (SWEPT AREA OF ROTOR)*

*Remember: In wind power generation, velocity is a cubic function. If the wind velocity is doubled, eight times the amount of power is produced (2*2*2). This means that wind power generation is very sensitive to wind speed.*

turbulent wind areas. These anemometers might be just fine for their purpose, but were probably not installed at the right hub-height or in the perfect area to collect wind information for your project. If you are using local data, make sure you evaluate the site to see that it has good exposure to the wind, is free of turbulent air flows, and is capturing the wind resource at a hub height similar to your potential project. In some states, anemometer loan programs for small wind are used to collect data. That data is often posted on line and may be a good source for your project. Neither Montana nor Wyoming currently have an anemometer loan program in place.

The free mapping tools based on existing local data are often the best information available to you. Remember that these sources do not give you nearly as accurate data as on-site data collection would provide. Wind speed is key to accurately calculating both the energy production and economic return of the small wind turbine. Error in the wind speed estimates will result in errors in these calculations. Most purchasers of small wind turbines will have to accept at least a moderate amount of uncertainty in the average annual turbine energy production. Here are a couple of questions to consider:

- **Are you reasonably confident that your wind speed information is accurate?** If your answer is "no" or "uncertain," you may wish to buy data or ask your installer to do a more in-depth assessment.

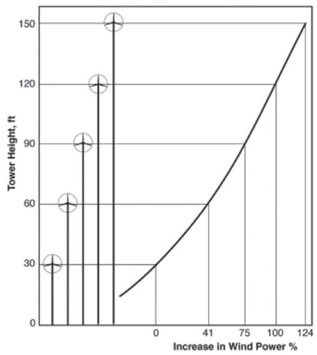
  ☐ Yes
  ☐ No
  ☐ Uncertain

- **Are you comfortable with the possibility that economic or energy output calculations might be off because of error in the wind speed estimate?** If you answered "no" or "uncertain" consider installing an anemometer or buying data to help reduce the possibility of error. The bottom line is that wind is a variable resource. Wind users accept that there may be error or variability in wind speed. Error (or uncertainty) in the long term average resource is different from variability. Even if an estimate for the long-term resource is spot on, the wind resource will vary from month to month and year to year. If you want more consistent energy output, you may wish to look at other technologies or invest in additional energy efficiency measures.

  ☐ Yes
  ☐ No
  ☐ Uncertain

Wind Shear

Wind shear is the change in wind velocity with elevation above ground. Wind shear is caused by surface topography, wind speed, and atmospheric stability. Wind shear is important to small wind because the power output of a turbine increases when wind speed increases.



Courtesy of KidWind

Tall towers can access higher wind speeds. Therefore, power production is increased by increasing the tower height. Energy generation can be maximized by selecting a tower height that places the bottom edge of the blade at least 30 feet above the tallest obstacle within 500 feet.

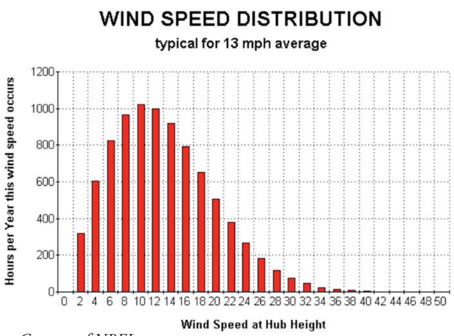
Wind Distribution

Wind varies by time of day, season, height above ground, and topography of the site. Wind speeds, in most of the world, are modeled using a statistical analysis called Weibull distribution. A Weibull distribution depicts the relationship between wind speed at a specific location and power production. Weibull calculations are important for a number of reasons. First, knowing the frequency of average wind speeds helps in selecting a turbine with an optimal cut-in speed (the wind speed at which the turbine starts to generate usable power) and the speed at which the turbine is designed to curtail power production. Second, the Weibull distribution can be used to estimate the average annual output for a given wind turbine at your site.

> **Weibull Values and Online Calculators**
>
> If you are using an online calculator, you may need to input the k value or Weibull. The Weibull (k) value reflects the width of the distribution. A lower value represents a broader distribution with a wider range of wind speeds. Where it is not possible to obtain sufficient information to calculate an actual Weibell distribution, for inland locations it is typical to assume a Weibell of 2, also known as a Rayleigh distribution.

What Does This Mean to Me?

Wind distribution is important. In the diagram on top of the next page, you see a Weibull distribution for a site with an average wind speed of 13 miles per hour. Notice that the wind blew more often at wind speeds of eight to 12 miles per hour than at the average wind speed of 13 miles per hour. An "average" by definition is the total of all the wind speeds divided by the number of times the wind speed was recorded. Even though the "average" wind speed is 13 miles per hour, the more frequent wind speeds are eight to 12 miles per hour. For example, if you bought a wind turbine designed for optimum power output at a 13 miles per hour because that was the average wind speed, the turbine may perform less

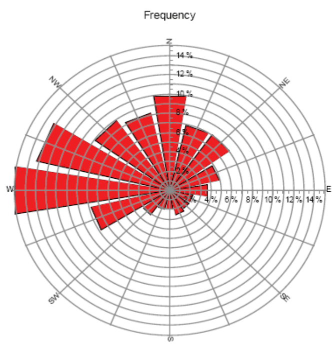


Courtesy of NREL

efficiently than if you had bought a turbine that had optimum performance at 10 miles per hour wind speed. This is why wind distribution matters!

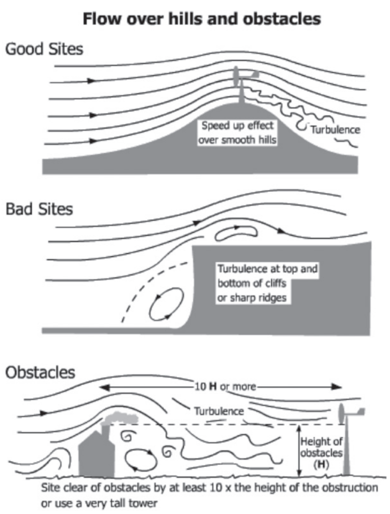
Wind Rose

A wind rose can be extremely useful when siting a wind turbine. A wind rose graphs the prevailing wind direction. This rose may show the percent of time the wind blows in a given direction and/or the proportion of energy produced by those winds. Usually, free wind roses do not include the energy information. In this drawing, the prevailing winds are from the west and north. Turbines should be installed to access the strongest prevailing winds. (Remember that the strongest wind might not be the most frequent!) Turbines should be sited upwind of any obstacles to maximize energy production. Wind roses vary from one location to the next. Wind roses from locations around the West are provided at www.wrcc.dri.edu/wraws/nidwmtF.html. Remember that the quality of the wind rose data may vary. If data is collected from a low tower height or in an area with ground clutter, the wind rose may not be accurate. It can, however, provide an estimate of the prevailing winds in your area.



Turbulence and Obstruction

Turbulence both decreases power output from the turbine and causes stress on the equipment. Trees, buildings, grain silos and other obstacles can cause turbulence. The region of disturbed flow downwind of an obstacle is twice the height of that obstacle and quite long. For example, a 30-ft tall house can create a region of turbulence that is 60 ft high and 600 ft long. This graphic depicts the turbulent influence of a structure on wind dynamics.



Air Turbulence and Obstruction Varies by Site. Courtesy of NREL

Turbulence and obstructed air flows may also be related to topography. The graphic illustrates characteristics of "good" sites for power generation versus sites with high levels of turbulent air flow.

Sheltering

In hilly terrain, the wind will follow channels, such as canyons. Placing your wind turbine on the leeward side of a hill or otherwise sheltering the turbine from the dominant wind will negatively impact long term energy output.

Air Density

Air density varies by temperature and elevation. In Montana and Wyoming, changes in air temperature mean that air density in winter months is typically better for wind power generation. At a given wind speed, a wind turbine will produce more energy in the winter, than in the summer months due to the colder, and thus more dense, air. However, a factor often overlooked in wind resource assessments is changes in air density given elevation. Many energy production calculators assume that your location is sea level. In Montana and Wyoming, many sites are over 5,000 feet above sea level. As elevation rises, air density declines such that (given other factors are constant) annual energy production of a turbine sited at 7,000 feet could be 20 percent lower than a similar turbine sited at sea level. To adjust for elevation, estimate energy production for sea-level and subtract 1.4 percent for every 500 feet above sea level. For more information on elevation adjustment, reference the University of Wyoming publication entitled, The Effect of Altitude on Small Wind Turbine Production.

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Notes

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